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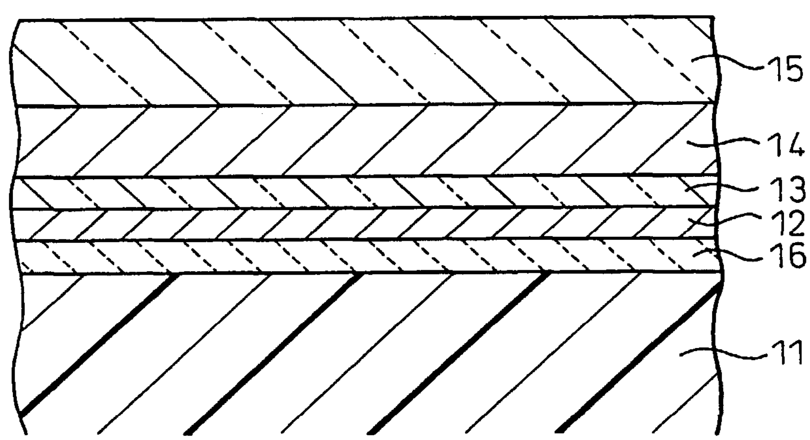
(54) Title: AN OPTICAL RECORDING MEDIUM AND METHOD FOR USING SAME

(57) Abstract



An optical recording medium comprising a substrate, and at least a recording layer and an upper inorganic layer formed in this order on said substrate, in which recording and reproducing are effected by applying an optical beam to said recording medium from an optical head located on the side of said upper inorganic layer, in that said upper inorganic layer is so constructed that a foreign material present on the top surface of said optical recording medium does not evaporate when said optical beam for recording is applied to said recording medium, preferably A) said upper inorganic layer comprises a first dielectric layer having such a thickness that, when said optical beam for recording is applied to said recording medium, the temperature of the top surface of said recording medium does not increase to a level at which a foreign material present on the top surface of said optical recording medium evaporates; or B) said upper inorganic layer comprises such a laminate of a second dielectric layer, a metal layer and a third dielectric layer in this order on said recording layer, whereby when said optical beam for recording is applied to said recording medium, the temperature of the top surface of said recording medium does not increase to a level at which a foreign material present on the top surface of said optical recording medium evaporates.

DESCRIPTION

AN OPTICAL RECORDING MEDIUM AND METHOD FOR USING SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical recording medium and to a method for recording and reproducing the optical recording medium. More specifically, the optical recording medium of the present invention is a type in which a laser beam is applied, by an optical head located at a very small distance from the surface of the medium, onto the medium from the side of a recording layer opposite to the substrate.

2. Description of the Related Art

Most optical recording mediums commonly used at present are of the type in which a laser beam is applied to a recording layer through a substrate.

In contrast, recently attracted attention is a type in which a laser beam is applied using an optical head located at a very small distance from the surface of a medium, using as a flying optical head having a flying slider similar to that of a hard disc on which an objective lens is mounted, onto the medium from the side of a recording layer without passing through the substrate (Japanese Magazine "Electronics" published by Ohm Co., May 1996, pp 87 - 91). This type of medium is called a "layer side incident type" medium.

In this layer side incident type medium, an actuator for focus control, as used in common optical heads, is not used and the constant flying height of the optical head from the surface of the medium makes the focal point of an optical beam coincide with a recording layer. As described in the above magazine, it is preferred that an optical head is located nearer to the surface of a recording medium, since it makes the diameter of an

optical beam at the focus point smaller and the recording density can be increased, and the gap between an objective lens and the surface of a recording medium is usually 1 μm or less.

Another layer side incident type has been proposed. That is, different from the small gap system described above, an optical head equipped with a focus control actuator, similar to that used for a conventional substrate-side incident type mediums, is used to record and reproduce information in an optical recording medium, but an optical beam is applied to the medium from the side of a recording layer without via the substrate (Magazine "O plus E" published by Shin-Gijutsu Communications, Vol. 20, No. 2, pp 183 - 186, Feb. 1998; and Presentation No. WA2 in "Optical Data Storage Conference Edition" 1998 OSA Technical Digest Series Volumn 8, May 10 - 13, 1998, pp 131 - 133).

The technologies of the above two references are intend to increase the recording density by combining an optical system having a high numerical aperture (NA) obtained by a combination of two special lenses, with the optical characteristics of an organic coating layer (an optically cured resin layer or a transparent layer) having a thickness of 100 μm formed on an upper dielectric layer, i.e., on the beam incident side, which has a possibility of providing a significant increase in the recording density in comparison with the presently used mediums. However, in this technology, the distance between an optical head and a recording layer increases by at least the thickness of the organic coating layer and the distance between an optical head and the surface of the medium increases due to the use of the same optical system as that of the substrate side incident type, whereby the density of the recording is limited.

In contrast, the layer side incident type medium in a small gap manner can theoretically attain a higher

recording density and is therefore attracting attention. Although a layer side incident type medium can have a higher recording density than conventional mediums and investigation thereof has been started, recording and reproducing at a practical level have not been attained yet and there will be various problems to be solved.

The present invention relates to an improvement of a layer side incident type medium in a small gap manner and solves the following problem which the present inventors found.

That is, the present inventors have made investigation of a layer-side incident type medium comprising a reflective layer, a lower dielectric layer, a recording layer and an upper dielectric layer in this order on a polycarbonate substrate, and found a problem that an objective lens mounted on a flying optical head is clouded or becomes dirty. In the reproduction there was no problem in tracking control. However, once a laser beam of a relatively high power was applied for recording or erasing, tracking control immediately became difficult due to clouded objective lens, and even reproducing became impossible.

The object of the present invention is to solve the above problem, and provide a layer side incident type medium in a small gap manner in which clouding of a lens is prevented and which can be used for a long time.

SUMMARY OF THE INVENTION

The above and other objects are attained in accordance with the present invention by providing an optical recording medium comprising a substrate, and at least a recording layer and an upper inorganic layer formed in this order on said substrate, in which recording and reproducing are effected by applying an optical beam to said recording medium from an optical head located on the side of said upper inorganic layer, characterized in that said upper inorganic layer is so

constructed that a foreign material present on the top surface of said optical recording medium does not evaporate when said optical beam for recording is applied to said recording medium. Particularly, the upper inorganic layer is constructed so as to have one of the following two features:

A) said upper inorganic layer comprises a first dielectric layer having such a thickness that, when said optical beam for recording is applied to said recording medium, the temperature of the top surface of said recording medium does not increase to a level at which a foreign material present on the top surface of said optical recording medium evaporates (first aspect of the invention); and

B) said upper inorganic layer comprises a laminate of a second dielectric layer, a metal layer and a third dielectric layer in this order on said recording layer, whereby when said optical beam for recording is applied to said recording medium, the temperature of the top surface of said recording medium does not increase to a level at which a foreign material present on the top surface of said optical recording medium evaporates (second aspect of the invention).

In the specification, the term "recording" is used in the broad sence and include "writing" (also sometimes called as "recording" in the narrow sence) and "erasing". In a phase change-type optical recording medium, direct over-write is typically made in which a pulse beam having a high energy for writing and an intermediate energy for erasing is used in recording, while a beam having a low energy is used in reproduction. In a magneto-optical recording medium, recording is typically made by first scanning an erasing beam having an interminate energy and then scanning a writing beam having a high energy. In the present invention, the temperature of the surface of a medium should be suppressed during recording in the broad sence, i.e., during both writing and erasing.

By the diligent investigation by the present inventors, it was found by analysis that the cloudiness or dirt on the objective lens was adhesion of a foreign material, specifically adhesion of water or organic materials incorporated in water in which an organic material is incorporated. The present inventors repeated experiments and consideration to identify the source of the dirt and the mechanism of dirt adhesion to a lens, and concluded that the cause is a foreign material adhered to the surface of a recording medium, i.e., a layer side incident type optical recording medium, specifically adhered water and/or an organic component such as oil mist in air which was incorporated in or adhered to the adhered water.

The mechanism of lens clouding was considered to be that, due to application of a laser beam having a relatively high power, the surface of a medium reaches a high temperature, by which water and organic components adhered to the surface of the medium evaporate and condense on an objective lens of a flying optical head. Nevertheless, since an optical recording medium is a removable medium and is handled in air, which is different from a hard disc, it is impossible to prevent an optical recording medium contacting with moisture or organic materials in the air and therefore presence or adhesion of moisture or organic materials in the air on the surface of a medium is usually inevitable.

The present inventors reached the idea that the above problem could be solved by making the temperature of the surface of a medium lower than the temperature at which the materials adhered on the surface evaporate and the inventors investigated this idea in various ways.

First, the present inventors made simulation of the temperature of the surface of optical recording mediums having the conventional medium constructions during recording and reproducing and found that it was impossible to desirably lower the temperature of the

surface of a medium in such constructions.

Here, in accordance with the first aspect of the present invention, the present inventors reached an idea that the thickness of the upper dielectric layer could be increased to lower the temperature of the surface of a medium, and the present inventors sought to determine if a medium can have a desired lowered temperature of the surface of a medium while maintaining desired properties for an optical recording medium when the thickness of the upper dielectric layer was increased. Fig. 2 shows the relationship between the reflectivity of a medium and the thickness of the upper dielectric layer as a result of computer simulation. As shown in Fig. 2, it was confirmed that even if the thickness of the upper dielectric layer is increased, the same reflectivity and therefore a reflectivity required for an optical recording medium can be obtained, and it was therefore expected that the temperature of the surface of a medium can be suppressed during application of a laser beam by the thermal insulation of the increased thickness of the upper dielectric layer.

Based on the above results of computer simulation and consideration, optical recording mediums having an increased thickness of the upper dielectric layer were manufactured and examined for recording and reproducing using a flying optical head, and, as a result, a significant improvement, as expected, was confirmed and thus the present invention, particularly the first aspect of the present invention, was completed.

Similarly, in accordance with the second aspect of the present invention, the present inventors reached an idea that the upper dielectric layer as in a conventional medium could be divided into two dielectric layers and a metal layer having a high thermal conductivity be inserted between the two dielectric layers to lower the temperature of the surface of a medium. The two dielectric layers and a metal layer therebetween as a

whole are referred to as "inorganic protecting layer" or "an upper inorganic layer" hereinafter. The present inventors then examined if an optical recording medium can have a desired lowered temperature of the surface of an optical recording medium while maintaining the desired properties for an optical recording medium when an upper inorganic layer as above is used and the construction of the upper inorganic layer was varied and adjusted.

Optical recording mediums having an upper inorganic layer comprising the three layers as above were manufactured and examined for recording and reproducing using a flying optical head, and, as a result, a significant improvement, as expected, was confirmed and thus the second aspect of the present invention was completed.

As can be seen from the above, in the present invention, the foreign materials are foreign materials adhered to the top surface of an optical recording medium and it is necessary that the temperature of the surface of the medium during application of an optical beam for recording should be kept lower than a temperature at which the foreign materials evaporate. The main foreign material is water. It is therefore preferred that the temperature of the surface of the medium is kept not higher than 150°C, more preferably not higher than 100°C.

In accordance with the present invention, the following method is also provided:

a method for recording and reproducing an optical recording medium,

providing an optical recording medium comprising a substrate, and at least a recording layer and an upper inorganic layer formed in this order on said substrate, and

recording and reproducing by applying an optical beam to said recording medium from an optical head located on the side of said upper inorganic layer,

wherein said upper inorganic layer is so constructed

that a foreign material present on the top surface of said optical recording medium does not evaporate when said optical beam for recording is applied to said recording medium.

Preferably, the upper inorganic layer has one of the two features A) and B) as described above.

BRIEF DESCRIPTIONS OF THE DRAWINGS

Fig. 1 shows a system for optically recording a recording medium or optical disc by applying an optical beam from the layer-side of the medium, and not through the substrate, by using a flying optical head;

Fig. 2 shows the relationship between the reflectivity of a medium and the thickness of the upper dielectric layer; and

Figs. 3 to 5 are sectional views of optical recording mediums in accordance with the present invention.

DETAILED DESCRIPTIONS OF THE INVENTION

The optical recording medium of the present invention comprises, on a substrate, at least a recording layer and an upper inorganic layer, in this order, in which an optical beam is applied to the medium from the upper inorganic layer side for recording and reproducing. Preferably, the medium comprises a reflective layer, a lower dielectric layer, a recording layer and an upper dielectric layer in this order on the substrate.

The layer side incident type optical recording medium, in which an optical beam is applied to the medium from the upper inorganic layer side for recording and reproducing, using a flying optical head, as an example, is briefly described.

Referring to Fig. 1, on or above an optical recording medium or disc 1 comprising a substrate 1a and a laminate 1b including a recording layer, a flying slider 2 suspended from a suspension 3 is shown. When

the optical disc 1 is being rotated, the flying slider 2 flies above the optical disc 1 and the flying height H depends on the rotation speed of the optical disc 1 and the shape, weight, etc. of the flying slider 2 and can be in the order of 100 nm, for example. On the flying slider 2, objective lenses, which comprises a combination of two lenses 4 and 5 in this example, is mounted. A laser beam 6 is applied through an optical system. In the case of a magneto-optical recording medium, a magnetic field (not shown) is further provided.

The recording and reproducing are performed in the same namer as in the conventional optical recording system except that the optical system uses a flying optical head and a laser beam is applied to the medium from the layer side, not through the substrate.

(First Aspect of the Invention)

The first aspect of the present invention is described below.

Fig. 3 shows an example of an optical recording medium of the first aspect of the present invention. In Fig. 3, 11 denotes a substrate, 16 a thermally insulating layer, 12 a reflective layer, 13 a lower dielectric layer, 14 an optical recording layer such as a phase change-type recording layer and 15 an upper dielectric layer. This reflective layer construction comprising a reflective layer 12 and a lower dielectric layer 13 is most commonly used in the current magneto-optical and phase change-type recording mediums and provides a high C/N (reproducing signal output to noise ratio), since it prevents unnecessary heat diffusion, as it is called as "rapid cooling construction", whereby it can be preferably used in an edge recording system in which an edge of a recording spot is utilized for information recording. Also, in the present invention, this construction having a reflective layer is preferably used for a high recording density.

The thickness of the upper dielectric layer 15 is

next described below with reference to Table 1 and Fig. 2. Table 1 shows the construction and optical properties of the layers of a phase change-type recording medium which was used in the examination. In Table 1, the materials and optical properties of the substrate are not shown since they have nothing to do with to the reflectivity.

Table 1

Construction	Material	Thickness (nm)	Refractive index	Extinction coefficient
Substrate	--			
Reflective layer	AlCr	150	1.226	5.417
Lower dielectric layer	$ZnS \cdot SiO_2$	18	2.18	0.02
Recording layer	GeSbTe	22	4.099	3.788
Upper dielectric layer	$ZnS \cdot SiO_2$	0 - 600	2.18	0.02

Fig. 2 shows the result of simulation of the light reflectivity of the optical recording medium having the above construction as shown in Table 1, when the thickness of the upper dielectric layer 15 is varied, in which the abscissa is the thickness of the upper dielectric layer 15 and the ordinate is the reflectivity. It is shown in Fig. 2 that due to the light interference, the first peak of the reflectivity of the medium appears around 150 nm of the thickness, the second peak at around 300 nm and the third peak at around 450 nm. This feature of the reflectivity was also confirmed in the experiment for optical recording mediums which were actually manufactured.

In the conventional optical recording mediums, the thickness of the upper dielectric layer used was in the first peak region since there was no need to use a larger thickness as that of the second or further peak and such a larger thickness of the layer decreases the productivity.

Here, the peak region is defined as a region including the peak wherein the reflectivity of a medium has a reflectivity equal to or exceeding the reflectivity required for recording and/or reproducing as prescribed in the regulations, etc. Specifically, in an example of Fig. 2, when the lower limit of the reflectivity is 20%, the first peak region is a region from about 90 nm to about 195 nm of the thickness of the upper dielectric layer.

The reflectivity of an optical recording medium which is required for a magneto-optical recording medium or a phase change-type optical recording medium is usually in a range of 20 to 50% although it depends on the design of a drive or the standards.

Examples of the standards for optical recording mediums are ISO/IEC 13963 in which the reflectivity is 12 to 25% for a 3.5 inch magneto-optical recording medium with a 230 MB capacity; ISO/IEC 16824 in which the reflectivity at groove land regions is 15 to 25% for a 120 mm DVD-RAM with a 2.6 MB capacity; and ISO/IEC 16448 in which the reflectivity of the single layer is 45 to 85% and the reflectivity of the dual layer is 18 to 30% for a 120 mm DVD-RAM with a 4.7 GB capacity or a 9 GB dual layer capacity.

In the first aspect of the present invention, the thickness of the upper dielectric layer is selected so as to have a temperature of the surface of a medium on the light incident side lower than that at which a foreign material adhered to the surface of the medium does not evaporate and a reflectivity of the medium equal to or higher than the required value. This thickness of the upper dielectric layer is preferably a thickness equal to or greater than the second peak region. By using such a thick upper dielectric layer, the temperature of the surface of the medium can be suppressed even if the temperature of the recording layer is raised to a high temperature. If a thickness equal to or greater than the

third peak region is used, a more significant effect can be obtained. Incidentally, when increase in the temperature of the surface of the medium is suppressed, the requirement for a heat resistance of a lubricant layer, which may be formed on the upper dielectric layer, may be significantly alleviated, which is an additional effect.

In the above consideration and experiment, a phase change-type optical recording medium in which the reflectivity decreases for recording in comparison with that for erasing is used and it is obvious that the same effect can be obtained in a reversed-type medium, i.e., a phase change-type optical recording medium in which the reflectivity increases for recording in comparison with for erasing. Also, it is obvious that the same effect can be obtained in a magneto-optical recording medium.

The thickness of the upper dielectric layer 15 is preferred to be thicker for lowering the temperature of the surface of the medium and is preferred to be thinner for productivity. Therefore, it is preferred that the thickness of the upper dielectric layer 15 does not exceed 1 μm. Also, when the thickness exceeds 1 μm, the stress of the layer becomes too high and the layer tends to peel off or be warped.

The distance between the top surface of the medium and the objective lens of the optical head is preferably as small as possible to increase the recording density. Accordingly, the present invention is particularly preferably applied to the case where the distance between the top surface of the medium and the objective lens of the optical head is as small as about 1 μm or less. Here, the objective lens means the output end of the optical system of an optical beam and includes a solid immersion lens as described in the magazine "Electronics" mentioned before.

The refractive index of the upper dielectric layer

is preferably not less than 1.70. It is known that insertion of an oil having a high refractive index between the objective lens and the sample or object to be observed in the microscopy increases the resolving power of the microscope. In the present invention, by using an upper dielectric layer having a high refractive index, the spreading of the focus (beam waist) of an optical beam can be further suppressed. The refractive index of the upper dielectric layer is a complex refractive index obtained by calculation when the upper dielectric layer comprises a plurality of dielectric layers. This complex refractive index can be derived from the total transfer matrix obtained by the product of respective transfer matrixes of multilayer films (see Metal-Dielectric Multilayer, J. Macdonald, Adam Hilger (London), page 8, 1971).

The upper dielectric layer may be a layer of calcogenides, nitrides and oxides such as $ZnS \cdot SiO_2$, ZnS, SiN, GeN, AlSiN, Al_2O_3, SiO_2, Ta_2O_5, TiO_2 and Y_2O_3 and combinations thereof. The composition of these layers may be stoichiometric or near stoichiometric. Among them, a layer of $ZnS \cdot SiO_2$ is preferable since it has a low thermal conductivity and a stable amorphous state which cannot be easily crystallized by heat. The upper dielectric layer may be formed by physical vapor deposition such as sputtering. The layer of $ZnS \cdot SiO_2$ may be formed by sputtering a mixture of ZnS and SiO_2 in a ratio of about 80 mol% to about 20 mol%.

Fig. 4 shows a preferred embodiment of the first aspect of the present invention in which the upper dielectric layer 15 is divided into two a first upper dielectric layer 15a and a second upper dielectric layer 15b. The first upper dielectric layer 15a has a low thermal conductivity and the second dielectric layer 15b has a high hardness.

If the upper dielectric layer comprises a plurality of layers, the total thickness is selected so as to keep

the temperature of the surface of a medium lower than the temperature at which a foreign material on the medium evaporate. For example, a thickness of the second peak region or thicker in Fig. 2 may be used. The hard second upper dielectric layer may be made of silicon nitride or hydrogenated diamond-like carbon (DLC). In such a case, the thickness of the hard second upper dielectric layer is usually in a range of 10 to 150 nm and the remaining thickness of the upper dielectric layer is composed of a low-thermal-conductivity upper dielectric layer.

The low-thermal-conductivity upper dielectric layer of the upper dielectric layer preferably has a thermal conductivity as low as 5 Watt/(m × K) or lower where m stands for the meter and K stands for the absolute temperature, which is indirectly estimated from the simulation, etc., since the direct measurement of the thermal conductivity of the dielectric layer is difficult.

In Fig. 4, an upper barrier or crystallization accelerating layer 17 and a lower barrier or crystallization accelerating layer 18 are shown although these layers are optional.

(Second Aspect of the Invention)

The second aspect of the present invention is described below.

Fig. 5 shows an example of an optical recording medium of the second aspect of the present invention. In Fig. 5, 21 denotes a substrate, 26 a thermally insulating layer, 22 a reflective layer, 23 a lower dielectric layer, 24 an optical recording layer such as a phase change-type recording layer, and 25 an inorganic protective layer. The inorganic protective layer 25 comprises a first upper dielectric layer (top upper dielectric layer) 25a, a second upper dielectric layer (bottom upper dielectric layer) 25b and a metal layer 25c. This reflective layer construction comprising a reflective layer 22 and a lower dielectric layer 23 is

most commonly used in the current magneto-optical and phase change-type recording mediums and provides a high C/N (carrier to noise ratio), as described with reference to the first aspect of the present invention. In Fig. 5, an upper barrier or crystallization accelerating layer 27 and a lower barrier or crystallization accelerating layer 28 are also shown although these layers 17 and 18 as wall as the thermally insolating layer 26 are optional.

The inorganic protecting layer is described below. The metal layer 25c acts as a heat diffusion layer to prevent the elevation of the temperature of the surface of the medium, which is the most important role of the present invention. That is, during recording or erasing, an optical beam is mainly absorbed by a recording layer and transformed into heat. As this heat in the recording layer moves to the surface of the medium, the temperature of the surface of the medium raises. In the second aspect of the present invention, however, since there is a metal layer having a high thermal conductivity in the path from the recording layer to the surface of the medium, the heat is diffused transversely along the metal layer, by which an increase in the temperature of the surface of the medium is prevented. This was confirmed by experiments.

The metal layer preferably has a high thermal conductivity to act as a heat diffusion layer. Therefore, the metal layer preferably comprises gold (Au), silver (Ag), copper (Cu) and aluminum (Al) and alloys thereof. Particularly, an alloy comprising Ag with 0.5 at% (atomic%) or more of Cu has a high thermal conductivity, is cheap in comparison with Au, has a higher thermal conductivity in comparison with Al, and is excellent in corrosion resistance in comparison with Ag alone, and thus it is preferable in the present invention. A content of Cu in an Ag alloy of not more than 20 at% is preferred since the wavelength dependency

on the performance is lower and it can be used with an optical head for various wavelength. It is also possible that up to about 3 at% of Ti, Ta, Pd, Nb, Ni or the like is added to an alloy of Ag and Cu.

It is difficult to identify the thermal conductivity of the metal layer since the measurement of the thermal conductivity is difficult. However, it is considered from the simulation, etc. that the thermal conductivity of the metal layer should be about 50 Watt/(m × K) or more where m stands for the meter and K stands for the absolute temperature.

The thickness of the metal layer is preferably in a range of 5 to 50 nm. If the thickness is less than 5 nm, the effect of heat diffusion is insufficient and the effect of prevention of the increase in the temperature of the surface of a medium is low. If the thickness is higher than 50 nm, the reflectivity of the medium becomes too high and far outside the range of about 20% to about 50% as the standard reflectivity at present of the magneto-optical recording medium or the phase change-type optical recording medium. Although the required reflectivity of a medium may be adjusted depending on the design including the amplifier gain of a drive, a new version should have a compatibility with an old version and therefore too high a reflectivity should be avoided. Further, the present invention is preferably applied to a phase change-type optical recording medium in which reproducing signal is obtained utilizing the difference in the reflectivity of the medium between when the recording layer is a crystalline phase and when it is in an amorphous phase. However, if the metal layer is thicker than 50 nm in the phase change-type optical recording medium, the difference of the reflectivity of the medium between when the recording layer is a crystalline phase and when it is an amorphous phase is small and an excellent C/N ratio cannot be obtained, which is very disadvantageous.

Moreover, in a phase change-type optical recording medium in which the metal layer has a thickness of 20 to 50 nm, it is possible that the reflectivity of the medium when the recording layer is in an amorphous phase (the recorded mark portion) can be made higher than that when it is a crystalline phase (the erased portion). In this medium, since the reflectivity of a medium increases when it is recorded, it is called a "Low to High construction" ("Low to High Polarity"), which is known to be able to decrease the jitter in high density recording. Specifically, in a phase change-type optical recording medium which is characterized by easy direct over-writing, it is known that if the raised temperature of the recording layer is different between a recorded mark portion (amorphous portion) and an erased portion (crystalline portion), a recorded mark portion newly written on a previous recorded-mark-portion (amorphous portion) and a recorded mark portion newly written on a previous erased-portion (crystalline portion) have different size and shape to each other, deteriorating the signal quality (increased jitter). Accordingly, writing a new recorded mark portion on an erased portion (crystalline portion) requires a higher heat capacity than writing a new recorded mark portion on an amorphous portion by a heat of fusing the crystal phase. It is therefore preferred that the medium absorbs the optical beam in an increased amount of the energy corresponding to the heat capacity of fusing the crystal phase, in other words, it is preferred that the reflectivity of the medium should be smaller by a level corresponding to the above heat capacity. This is the reason why a medium in which the reflectivity of a medium is smaller at the erased portions (crystalline portions) than at the amorphous portions is preferred.

The inorganic protecting layer 25 further comprises a first upper dielectric layer 25a between the recording layer 24 and the metal layer 25c and comprises a second

upper dielectric layer 25b on the metal layer 25c.

The refractive index of the first and second upper dielectric layers are preferably not less than 1.70. In the present invention, by using an upper dielectric layer having a high refractive index, the spreading of the focus (beam waist) of an optical beam can be further suppressed.

The first upper dielectric layer 25a has a role of providing an adequate recording sensitivity and a role of protecting the recording layer 24 and the metal layer 25c. If there is no first upper dielectric layer 25a, the elevation of the temperature of the recording layer during the application of an optical beam is very small and the recording sensitivity is very low and fusion of the recording layer or mixing the elements of the recording layer and the metal layer cannot be prevented. From the viewpoint of the recording sensitivity, the first upper dielectric layer preferably has a low thermal conductivity, is thermally stable or is not deteriorated at a high temperature, and is a stable amorphous material.

The first upper dielectric layer may be a layer of calcogenides, nitrides and oxides such as $ZnS{\cdot}SiO_2$, ZnS, SiN, GeN, AlSiN, Al_2O_3, SiO_2, Ta_2O_5, TiO_2 and Y_2O_3 and combinations thereof. The composition of these layers may be stoichiometric or near stoichiometric. Among them, a layer of $ZnS{\cdot}SiO_2$ is preferable since it has a low thermal conductivity and is a stable amorphous material which cannot be easily crystallized by heat. The first upper dielectric layer may be formed by physical vapor deposition such as sputtering. The layer of $ZnS{\cdot}SiO_2$ may be formed by sputtering a mixture of ZnS and SiO_2 in a ratio of about 80 mol% to about 20 mol%.

The first upper dielectric layer preferably has a thermal conductivity as low as 5 Watt/(m × K) or lower where m stands for the meter and K stands for the absolute temperature, which is indirectly estimated from

the simulation, etc., since the direct measurement of the thermal conductivity of the dielectric layer is difficult.

The thickness of the first upper dielectric layer is preferably not less than 10 nm from the viewpoint of the recording sensitivity and protection of the recording layer and preferably does not exceed 1 μm from the viewpoint of productivity. Some dielectric materials may give too high a stress to a first upper dielectric layer if the thickness of the layer exceeds 1 μm, resulting in peeling off or warping of the layer.

The second upper dielectric layer 25b has a role of preventing corrosion of the metal layer 25c, preventing the damage of the surface of a medium by contact by an optical head, and preventing an increase in the temperature of the surface of a medium. From this viewpoint, the thickness of the second upper dielectric layer 25b is preferably not less than 10 nm and more preferably not less than 40 nm to obtain further advantageous effects of preventing damage to the surface of the medium and suppressing an increase in the temperature of the surface of the medium. The effect of suppressing the raise in the temperature of the surface of the medium may be also advantageous since it significantly alleviates the requirement of heat resistance for a lubricating layer which may be provided on the second upper dielectric layer 25b. However, the thickness of the second upper dielectric layer 25b preferably does not exceed 1 μm from the viewpoint of productivity. If the thickness of the layer exceeds 1 μm, some dielectric material may cause too high a stress to a second upper dielectric layer resulting in peeling-off or warping of the layer.

Further, even if dielectric layers having a refractive index of 1.70 or more are used, the distance between the recording layer 24 and the objective lens of

the optical head is preferably as small as possible to attain a higher recording density. Accordingly, it is preferred that the total of the thickness of the inorganic protecting layer 25, i.e., the total thickness of the first and second upper dielectric layers 25a and 25b and the metal layer 25c, does not exceed 1 μm.

The material of the second upper dielectric layer 25b may be the same as that of the first upper dielectric layer 25a. Further, the second upper dielectric layer directly faces a flying optical head and a head slider contacts and may attack the second upper dielectric layer 25b. A hard dielectric layer is therefore preferable to resist the contact and attack. Such a hard second upper dielectric layer may be of silicon nitride or hydrogenated diamond-like carbon (DLC).

(Other Elements of the Medium)

It is preferred that a barrier layer 17 or 27 for preventing diffusion of components of the upper inorganic layer into the recording layer is inserted between the upper inorganic layer and the recording layer, to stabilize the quality. Moreover, a crystallization accelerating layer may be inserted adjacent to, and in contact with, the recording layer to provide a phase change-type optical recording medium which can be used at a high rotation speed. Also, from the same reason, a barrier layer or a crystallization accelerating layer 18 or 28 may be inserted between the lower dielectric layer 13 or 23 and the recording layer 14 or 24.

A typical example of the barrier layer is a GeN layer and a SiN layer, in which the ratio between Ge/N and Si/N is supposed to be 3/4 and close to the stoichiometric ratio although the analysis is not easy. Also, a layer of GeN to which Cr is added, i.e., a layer of GeCrN and an SiAlN layer are also used. A GeCrN layer is formed by sputtering a target of a Ge alloy containing Cr in an amount of 10 to 30 at% in an atmosphere of a

mixed gas of Ar and N_2 (about 10 to 50% of N_2). An SiAlN layer may be formed by sputtering an SiAl target in a mixed gas of Ar and N_2. Since a nitride is generally dense and is excellent in its heat resistance, the nitride layer has a high effect of preventing diffusion, into a recording layer, of S atoms of $ZnS \cdot SiO_2$ which is commonly used in a phase change-type optical recording medium. When these nitride layers are provided in contact with a GeSbTe layer, a typical phase change-type optical recording layer, the sensitivity of erasing of the medium is improved and it is considered that it has a high crystallization acceleration effect. Although the theoretical reason of accelerating the crystallization is not clear, it is considered that the above nitride layers have an effect of accelerating or increasing the nucleation for crystallization when the GeSbTe layer is heated to a crystallizing temperature.

A lubricating layer may be provided on the second upper dielectric layer, if necessary, to alleviate the impact caused by the contact and attack of the optical head as long as it does not damage the optical properties.

In the magneto-optical recording layer of a magneto-optical recording medium, an optical beam, typically a laser beam, is applied to raise the temperature of the recording layer, whereby the coercive force of the recording layer is reduced and the magnetic moment of the heated portion of the recording layer is reversed by an external magnetic field, to thus make recording and/or erasing. The temperature of the recording layer increases up to about 200°C.

In the phase change-type optical recording layer of a phase change-type optical recording medium, an optical beam, typically a laser beam, is applied to change between the amorphous and crystal phases of the material, in other words, cause a phase change, whereby the phase change is utilized for recording and/or erasing. The

temperature of the recording layer elevates up to about 600°C during recording and up to about 170°C during erasing. The phase change-type optical recording medium is advantageous since the cost of the materials is low in comparison with the magneto-optical recording material, the drive can be cheap in comparison with the magneto-optical recording since the mechanism of recording and erasing is as simple as utilizing the change of phase, and it is easy to make it compatible with a read only optical disc (CD-RCM, etc.).

The magneto-optical recording layer of a magneto-optical recording medium is known and may be, for example, of rare earth and transition metal alloys such as TbFeCo. The phase change-type optical recording layer of a phase change-type optical recording medium is known and may be, for example, carcogenide alloys such as GeSbTe and InSbTe. The thickness of the recording layer is not particularly limited but is typically in a range of 12 to 30 nm.

The present invention is more preferably applied to the phase change-type optical recording medium since the temperature of the recording layer increases up to a higher temperature in the case of the phase change-type optical recording medium (for example, 600°C) in comparison with the magneto-optical recording medium (for example, 200°C) and the problem of clouding or dirt is more severe at a higher temperature of the surface of the medium. The effect of the present invention is more apparently and advantageously obtained in the phase change-type optical recording medium.

The reflective layer is typically made of a Al alloy containing a 2 to 5 % of Ti, Ta, Cr, Au and the like. Alternatively, an Ag alloy or an Au alloy may be also used. The material and thickness of the reflective layer are not particularly limited in the present invention.

The thickness of the reflective layer is typically in a range of 40 to 200 nm.

The lower dielectric layer may be similar to the upper dielectric layer.

The thickness of the lower dielectric layer is typically in a range of 15 to 50 nm.

The substrate is not particularly limited in the present invention and can be of any known material such as glass and plastic, since the substrate does not relate to the optical properties of the medium in the present invention. Among these materials, polycarbonate resin is preferred since it is excellent in cost and mechanical properties. An amorphous aliphatic polyolefin resin is preferred when low water absorption is required.

When the substrate is low in its heat resistance, a thermally insulating layer may be disposed between the substrate and the reflective layer. The thermally insulating layer has an effect of preventing deformation of the substrate due to the effect of the heat generated in the recording layer. Particularly, in the step of the initial heat treatment for crystallization or initialization in which the medium is heated in a wide area at once, the substrate may be deformed more easily and the effect of the thermally insulating layer is significant in this step. The thermally insulating layer should have a low thermal conductivity and have a thickness of 2 nm or more.

The manner of conduction of the heat from the recording layer which is heated is considered as below. The heat of the recording layer normally passes though the lower dielectric layer and diffuses along the reflective layer of an Al alloy having a high thermal conductivity, while a portion of the heat of the reflective layer is conducted to the substrate. If the heat of the reflective layer diffuses only along the reflective layer, the problem of raising the temperature of the substrate does not arise.

Therefore, the thermal conductivity of the thermally insulating layer is determined in relation with the

thermal conductivity of the reflective layer. If the thermal conductivity of the reflective layer is high, the heat rarely reaches the substrate and thermal insulation of the thermally insulating layer is not necessary. If the thermal conductivity of the reflective layer is low, the thermal conductivity of the thermally insulating layer should be sufficiently low. The thermal conductivity of the thermally insulating layer should be not more than about one tenth of the thermal conductivity of the reflective layer. If the thickness of the thermally insulating layer is too thin, the effect of the thermally insulating layer is not obtained and it should be not less than 2 nm.

The material of the thermally insulating layer may be any one of the materials described for the upper dielectric layer, including calcogenides, nitrides and oxides such as $ZnS \cdot SiO_2$, ZnS, SiN, GeN, AlSiN, Al_2O_3, SiO_2, Ta_2O_5, TiO_2 and Y_2O_3 and combinations thereof.

The thermal conductivity of the thermally insulating layer is preferably similar to that of the upper dielectric layer or the first upper dielectric layer. It is considered to be about 5 Watt/(m × K).

The optical recording medium of the present invention is particularly advantageous when the medium is used in an optical head system in which the distance between the medium and an objective lens of the optical head system is as small as about 1.0 μm or less. A typical example of such an optical head system is a flying optical head. In the flying optical head, the distance between the medium and an objective lens of the optical head system is very small and clouding of the objective lens by the evaporated materials is very significant. The flying optical head is as shown in Fig. 1. The flying head flies at a certain distance from the surface of the medium on the air flow due to the rotation of the medium. Specifically, a slider supported

by a sheet spring structure, called a gimbals, holds an objective lens and flies at a certain distance from the surface of the medium by an air flow due to the rotation of the medium.

EXAMPLES

(Examples 1 to 4 and Comparative Examples 1 to 3)

A phase change-type optical recording medium having the structure similar to Fig. 4 (the barrier layer or crystallization accelerating layers 17 and 18 were not formed) was manufactured. Specifically, the medium comprised a substrate 11, a thermally insulating layer 16, a reflective layer 12, a lower dielectric layer 13, a recording layer 14, a first upper dielectric layer 15a and a second upper dielectric layer 15b. The thickness of the first upper dielectric layer 15a was varied. The thus manufactured phase change-type optical recording mediums were evaluated.

The used substrate 11 was a polycarbonate plastic substrate having a thickness of 1.2 mm and a diameter of 120 mm as well as a hole with an inner diameter of 15 mm and having the following format. The substrate 11 had V-shape spiral grooves from a radius of 25 mm to a radius of 58 mm for continuous servo, formed by injection molding. The grooves had a depth of 90 nm, a bottom width of 0.12 μm and a track pitch of 0.7 μm. The recording was made on the land.

On the above substrate, the following layers were formed to obtain a phase change-type optical recording medium in which an optical beam is applied from the layer side thereof. The thermally insulating layer 16, the lower dielectric layer 13 and the first upper dielectric layer 15a were an ZnS-SiO_2 layer obtained by sputtering a target of ZnS and SiO_2 in a mol% ratio of 80:20. The thickness of the thermally insulating layer 16 was 80 nm, that of the lower dielectric layer 13 was 18 nm and that of the first upper dielectric layer 15a was as shown in

Table 2. The refractive index of the $ZnS-SiO_2$ layer was about 2.18.

The recording layer 14 was a GeSbTe alloy layer deposited by sputtering a target of a GeSbTe alloy with the Ge:Sb:Te atomic ratio of 2:2:5 and had a thickness of 22 nm. The reflective layer 12 was an AlCr alloy layer deposited by sputtering a target of an AlCr alloy with an Al:Cr atomic ratio of 97:3 and had a thickness of 150 nm.

The second upper dielectric layer 15b was an SiN layer obtained by depositing an Si target in a mixed gas of Ar and N_2. The atomic ratio of the SiN layer was considered to be close to the stoichiometric ratio of 3:4 but an accurate analysis was difficult. The second upper dielectric layer 15b had a refractive index of 2.08 and a thickness of 120 nm.

The above inorganic layers were deposited on the substrate 11 by magnetron sputtering. The apparatus used was an inline sputtering apparatus (ILC3102-type manufactured by ANELVA Corp.) in which the target had a 8 inch diameter and was rotated in itself and also circulated around an axis with a certain radius. The thickness of the deposited layer was controlled by the depositing time.

Table 2 shows the thicknesses of the upper dielectric layers in Examples 1 to 4 and Comparative Examples 1 to 3 in which the thickness of the first upper dielectric layer was varied. Table 2 also shows the reflective index of the medium after the initial heat treatment for crystallization, and the ordinal number of the peak region to which the upper dielectric layers as a whole belonged. The peak region was as defined before in relation to the interference peak.

Table 2

No. of Sample	Thickness of layer			Ordinal number of peak region	Reflectivity of medium at wavelength of 685 nm
	First upper dielectric layer (nm)	Second upper dielectric layer (nm)	Total of upper dielectric layers (nm)		
Ex. 1	155	120	275	Second	32
Ex. 2	205	120	325	Second	38
Ex. 3	325	120	445	Third	36
Ex. 4	485	120	605	Fourth	37
Com. Ex. 1	15	120	135	First	38
Com. Ex. 2	45	120	165	First	42
Com. Ex. 3	75	120	195	First	25

The phase change-type optical recording mediums manufactured above were evaluated in an machine with a flying optical head having a laser diode of a wavelength of 685 nm. Since the direct measurement of the dirt or clouding was difficult, the disorder of the tracking error signal when a laser beam was applied was observed to evaluate the dirtiness or cloudiness of the objective lens. The flying optical head was a slider type as described before and shown in Fig. 1 in which an objective lens was mounted on a slider and the head was controlled to fly and have a distance of the objective lens of 0.38 μm from the surface of the medium. The tracking control was done by detecting the returning light with a two-dividing (dual) photodetector and using the push-pull signal or the difference between the two divided returning lights, called as the tracking error signal (hereinafter referred to as "TES"), for tracking. The rotation speed of the medium was constant, 8 m/sec. The specific procedures of the evaluation were as below.

A sample of a recording medium after the initial heat treatment for crystallization was set in the evaluation apparatus. An optical beam for reproduction with a power of 1.2 mW was repeatedly applied to the same track to measure the jump signal as the reference amplitude for evaluating the disorder of the TES. This reproduction by repeated application of an optical beam

was reproduction in the still mode for the erased portions. Since the track was spiral, the optical beam must move or jump a distance of one track pitch once per one rotation to repeatedly reproduce the same track, which is called as "track jump". If the repeated reproduction is normal in the still mode, the TES thereof is close to zero during one rotation, in which the optical beam is directed to the center of the track, except that a large output in the form of a sine wave (called as "jump amplitude") is observed when the tack jump occurs once per one rotation.

In general, the disorder of the TES is evaluated by the percent amplitude of the maximum amplitude in the one rotation, except for that at the track jump, in relation to the jump amplitude. This disorder should be not more than 43%, when the off-track width permitted in a medium having a 0.7 μm track pitch is 0.05 μm. While the permitted off-track width is not fixed since it depends on the S/N, etc. of the system, it was selected to be 43% considering the typical requirement for a conventional optical recording medium in which an optical beam is applied from the substrate side. If the disorder is larger than this evaluation reference of 43%, it means that an optical beam passes on a point or line outside the permitted range from the center of the track. If the disorder is further larger, an optical beam can not stay on the track, that is, the tracking control becomes impossible.

In all the samples of Examples 1 to 4 and Comparative Examples 1 to 3, normal tracking control was possible if the above reproduction only was made, and the disorder of the TES in one rotation was at most not more than 20% indicating that the medium was normal. The jump amplitude of the samples was measured.

Next, the evaluation of the dirt or clouding was made by the following test for the samples. In the evaluation, an intense optical beam (hereinafter referred

to as "evaluation laser power"), corresponding to a recording optical beam, was applied to the samples for a period of about one rotation, in the course of the still mode application of a reproducing optical beam having a power of 1.2 mW as above, and the disorder of the TES thereafter was measured for the evaluation.

Here, in general, an intense laser power is used for recording and erasing since a high temperature of the recording layer is necessary. In the tested samples, a laser power of about 4 mW was necessary for erasing a recorded mark and a laser peak power of about 7.8 mW was necessary for recording.

In the tests, an intense evaluation laser power was applied to the samples for a period of about one rotation, in the course of the still mode application of a reproducing optical beam having a power of 1.2 mW as above, and the disorder of the TES thereafter was measured for the evaluation. In this evaluation, the sample should of course pass at least the standard that the disorder of the TES after the application of a laser power of about 4 mW corresponding to an erasing power is not more than 43% of the above reference value. However there is no problem, in a practical use, if the disorder of the TES after the application of a laser power of about 6 mW, or less than about 7.8 mW of the peak power of a recording beam, is not more than 43% of the above reference value, since, in this test experiment, a continuous beam (DC laser beam with a constant intensity) is applied and the temperature of the medium therefore becomes higher than when a pulse beam, as in practical use, is applied as the evaluation power. This latter fact or critical value was confirmed in a separate experiment of reproduction of 1 - 7 modified random data. Therefore, the evaluation laser power of each sample when the disorder of the TES became the permission limit of 43% was determined. The sample which passes this reference can be satisfactory and has no problem in

practical use, as mentioned above. The results are shown in Table 3.

Table 3

	Total thickness of upper dielectric layer (nm)	Ordinary number of peak region	Evaluation laser power at the limit of TES disorder (mW)
Ex. 1	275	Second peak	6.0
Ex. 2	375	Second peak	6.4
Ex. 3	445	Third peak	7.1
Ex. 4	605	Fourth peak	7.8
Com. Ex. 1	135	First peak	3.8
Com. Ex. 2	165	First peak	4.3
Com. Ex. 3	195	First peak	5.2

As seen in Table 3, the evaluation laser power was low, 3.8 mW, in Comparative Example 1 and when the evaluation reference of 6 mW was applied, the tracking control was impossible, in other words, the disorder of the TES exceeded the evaluation limit and the flying optical head was unable to stay on the predetermined track.

In order to find the reasons for the above problems, observation of the recording mediums and the optical head was repeated before and after the tests. As a result, no problems were found in the mediums or on the surface of the mediums and it was found that liquid droplets were adhered on the surface, facing the medium, of the objective lens. Raman analysis and infrared absorption analysis were carried out to find mainly water in which a minor amount of hydrocarbons were incorporated. The hydrocarbons were in a very small amount and identification was not possible, but, it was considered that they were oil components usually present in the air. In Comparative Example 1, the disorder of the TES was observed even by the evaluation power of 2.5 mW. When the evaluation power was gradually raised, the disorder of the TES gradually increased and exceeded the limit of 43% at the evaluation power of 3.8 mW.

It can be seen in Table 3 that in Examples 1 to 4, the disorder of the TES was within the limit of 43% even

at the evaluation reference power of 6 mW, indicating that the mediums were practically useful mediums. In contrast, in Comparative Examples 1 to 3, the disorder of the TES was over the limit of 43%, at an evaluation power lower than the reference power of 6 mW, indicating that the mediums did not allow stable recording.

(Examples 5 to 19 and Comparative Examples 4 to 7)

A phase change-type optical recording medium having the structure similar to Fig. 5 (the barrier layers or crystallization accelerating layers 27 and 28 were not formed) was manufactured. Specifically, the medium comprised a substrate 21, a thermally insulating layer 26, a reflective layer 22, a lower dielectric layer 23, a recording layer 24, a first upper dielectric layer 25a, a metal layer 25c and a second upper dielectric layer 25b. The thicknesses of the first upper dielectric layer 25a, the metal layer 25c and the second upper dielectric layer 25b were varied. In Examples 5 to 19, the metal layer used was an AgCu layer containing 5 wt% of Cu. In Comparative Examples 4 to 7, mediums without a metal layer (Comparative Examples 4 and 5) and mediums having a thick metal layer of AgCu with a thickness of 55 nm (Comparative Examples 6 and 7) were manufactured.

The used substrate 21 was a polycarbonate plastic substrate which was the same as in Example 1.

On the above substrate, the respective layers were formed to obtain a phase change-type optical recording medium in which an optical beam is applied from the layer side thereof. The thermally insulating layer 26, the lower dielectric layer 23 and the first upper dielectric layer 25a were ZnS-SiO_2 layers obtained by sputtering a target of ZnS and SiO_2 in a mol% ratio of 80:20. The thickness of the thermally insulating layer 26 was 80 nm and that of the lower dielectric layer 23 was 18 nm. The thickness of the first upper dielectric layer 25a was one

of three types, i.e., 40 nm (Examples 5 and 6 and Comparative Example 4), 80 nm (Examples 7 to 10 and Comparative Examples 5 and 6) and 120 nm (Examples 11 to 19 and Comparative Example 7), as shown in Table 3. The refractive index of the ZnS-SiO_2 layer was about 2.18.

The recording layer 24 and the reflective layer 22 were the same as in Example 1. That is, the recording layer 24 was a GeSbTe alloy layer deposited by sputtering a target of a GeSbTe alloy with the Ge:Sb:Te atomic ratio of 2:2:5 and had a thickness of 22 nm. The reflective layer 22 was an AlCr alloy layer deposited by sputtering a target of an AlCr alloy with the Al:Cr atomic ratio of 97:3 and had a thickness of 150 nm.

The second upper dielectric layer 25b was an SiN layer obtained by depositing an Si target in a mixed gas of Ar and N_2. The atomic ratio of the SiN layer was considered to be close to the stoichiometric ratio of 3:4 but accurate analysis was difficult. The second upper dielectric layer 25b had a refractive index of 2.08 and the thickness of the second upper dielectric layer 25b was varied in a range of 42 nm to 225 nm as shown in Table 4.

The metal layer 25c was an AgCu layer obtained by sputtering an AgCu target with a Ag to Cu weight ratio of 95:5. The thickness of the metal layer 25c was varied in a range of 5 nm to 50 nm (Examples 5 to 19) and 55 nm (Comparative Examples 6 and 7).

The above inorganic layers were deposited on the substrate 21 by the same magnetron sputtering as in Example 1. Eight substrates were set in the inline sputtering apparatus (ILC3102-type manufactured by ANELVA Corp.) and the same layers were simultaneously deposited on the eight substrates. The thickness of the deposited layer was controlled by the time period for sputtering.

Table 4 shows the thicknesses of the first dielectric layer 25a, the metal layer 25c and the second dielectric layer 25b in Examples 5 to 19 and Comparative

Examples 4 to 7. Table 4 also shows the reflectivity of the medium having an amorphous recording layer immediately after the sputtering, the reflectivity of the medium having a crystalline recording layer after the initial heat treatment for crystallization, and the difference between the above two reflectivities. The results of the evaluation are also shown in Table 4. The medium, in which the difference of the above two reflectivities is minus in Table 4, is a so-called "Low to High construction (Low to High Polarity)" medium in which the reflectivities of the medium having an amorphous recording layer is greater than the reflectivity of the medium having a crystalline recording layer. This type of a medium is a preferred medium construction since it has a small jitter, i.e., dispersion of the signal detecting location in edge recording.

The evaluation of the samples of the optical mediums were made in the same manner as in Examples 1 to 4 and Comparative Examples 1 to 3.

In Comparative Examples 6 and 7, the reflectivity was too large and the focus control and the tracking control were difficult in the evaluation machine, so that a sufficient evaluation was not possible. In Comparative Examples 8 and 9, the reflective index was too small and it was clear that the C/N ratio (carrier to noise ratio) would be too small for practical use even if the evaluation machine was improved to control the location of the optical head.

In Examples 5 to 19 and Comparative Examples 4 and 5, the normal tracking control was possible when reproducing only was carried out and the jump signal of the mediums was measured. The disorder of the TES was at maximum not more than 20%, indicating that the mediums were normal. In other words, the laser power for reproducing was 1.2 mW and there was no problem at such a low power.

In comparative Example 4, the evaluation laser power was low, 3.5 mW, and the tracking control became impossible after the evaluation reference power of 6 mW, in other words, the TES signal was disordered more than the limit for evaluation and it was impossible for the optical head to stay on the predetermined track.

In order to find the reasons for the above problems, observation of the recording mediums and the optical head was repeated before and after the tests. As a result, no problems were found in the mediums or on the surface of the mediums and it was found that liquid droplets were adhered on the surface, facing the medium, of the objective lens. Raman analysis and infrared absorption analysis were made to find mainly water in which a small amount of hydrocarbons were incorporated. The hydrocarbons were in a very small amount and identification was not possible, but, it was considered that they were oil components usually present in the air. In Comparative Example 4, the disorder of the TES was observed even by the evaluation power of 2.5 mW. When the evaluation power was gradually raised, the disorder of the TES gradually increased and exceeded the limit of 43% at the evaluation power of 3.5 mW.

As seen in Table 4, in Comparative Example 5, since the reflectivity difference was 20.3%, it was expected to have an excellent C/N ration, but the disorder of the TES exceeded the permission limit of 43% at an evaluation laser power of 4.3 mW. In contrast, in Examples 5 to 19, the evaluation laser power was satisfactory, i.e., 6 mW or more, by only providing a metal layer of an AgCr alloy, in comparison with Comparative Examples 4 and 5.

In Examples 11 to 17 and 19, the mediums were a Low to High polarity medium as understood from the fact that the reflectivity difference was minus. As the absolute value of the reflectivity difference was 17% or more in each sample, the medium would provide a sufficient C/N ratio and, since the medium had a Low to High polarity,

it is expected that the jitter, i.e., the dispersion of the reproducing signal by the edge mark recording required for a high density recording, was small. In these samples of Examples, the evaluation laser power was satisfactory, i.e., 6 mW or more.

As described before, in Comparative Examples 6 and 7 in which the metal layer had a thickness of 55 nm, the evaluation of the sample by the evaluation machine used was impossible due to too high a reflectivity. While the evaluation was possible if the amplitude gain was improved, it was obvious that, even if an evaluation was made by modifying the evaluation machine, a sufficient C/N ration would not be obtained since the absolute value of the reflectivity difference would be too small. Therefore, such an evaluation was not made.

It can be seen from the above Examples that the dirtiness or clouding of the optical head can be prevented by providing the metal layer having a thickness in a range of 5 nm to 50 nm. It is preferable for increasing the recording density since a metal layer having a thickness in a range of 20 nm to 50 nm makes easy to provide a medium of Low to High polarity.

Table 4

	Second upper di-elec-tric layer	Metal layer	First upper di-electric layer	Reflectivity Crys-talline phase	Reflectivity Amor-phous phase	Reflectivity Differ-ence	Evaluation laser power at the limit of TES disorder (mW)
Ex. 5	42	10	40	30.3	9.7	20.7	6
Ex. 6	42	15	40	50.7	28.5	22.2	6.2
Ex. 7	60	5	80	40.8	20.6	20.2	6.3
Ex. 8	60	10	80	33.4	12.1	21.3	6.5
Ex. 9	60	15	80	33.8	11.0	22.1	6.8
Ex. 10	60	25	80	49.7	28.8	20.8	7.5
Ex. 11	60	20	120	5.6	23.7	-18.1	7.6
Ex. 12	60	30	120	14.8	37.1	-22.2	8
Ex. 13	60	40	120	27.3	49.9	-22.6	8.3
Ex. 14	60	45	120	40.7	61.1	-20.4	8.7
Ex. 15	60	50	120	53.1	70.1	-17.0	9.3
Ex. 16	120	10	120	16.1	34.7	-18.5	7.7
Ex. 17	120	15	120	26.0	47.7	-21.7	8
Ex. 18	225	5	120	25.2	5.6	19.6	8.2
Ex. 19	225	35	120	14.9	37.1	-22.3	9.2
Com. Ex. 4	42	0	40	18	5	15	3.5
Com. Ex. 5	60	0	80	52.1	31.8	20.3	4.3
Com. Ex. 6	60	55	80	76.5	65.1	11.4	N.D.
Com. Ex. 7	60	55	120	63.7	77.1	-13.4	N.D.

Note) N.D.: impossible to evaluate.

CLAIMS

1. An optical recording medium comprising a substrate, and at least a recording layer and an upper inorganic layer formed in this order on said substrate, in which recording and reproducing are effected by applying an optical beam to said recording medium from an optical head located on the side of said upper inorganic layer, characterized in that said upper inorganic layer is so constructed that a foreign material present on the top surface of said optical recording medium does not evaporate when said optical beam for recording is applied to said recording medium.

2. The optical recording medium according to claim 1, wherein said upper inorganic layer has one of the following two features:

A) said upper inorganic layer comprises a first dielectric layer having such a thickness that, when said optical beam for recording is applied to said recording medium, the temperature of the top surface of said recording medium does not increase to a level at which a foreign material present on the top surface of said optical recording medium evaporates; and

B) said upper inorganic layer comprises such a laminate of a second dielectric layer, a metal layer and a third dielectric layer in this order on said recording layer, whereby when said optical beam for recording is applied to said recording medium, the temperature of the top surface of said recording medium does not increase to a level at which a foreign material present on the top surface of said optical recording medium evaporates.

3. The optical recording medium according to claim 2, wherein said foreign material is mainly water.

4. The optical recording medium according to claim 2, wherein said top surface of said recording medium does not increase to more than 150°C when said optical beam for recording or reproducing is applied to

said recording medium.

5. The optical recording medium according to claim 2, further comprising a reflective layer between said recording layer and said substrate.

6. The optical recording medium according to claim 5, wherein said substrate is made of a plastic and said optical recording medium further comprises a thermally insulating layer between said substrate and said reflective layer.

7. The optical recording medium according to claim 6, further comprising a fourth dielectric layer between said recording layer and said reflective layer.

8. The optical recording medium according to claim 7, further comprising a barrier layer or a crystallization accelerating layer between said recording layer and said fourth dielectric layer.

9. The optical recording medium according to claim 2, further comprising a barrier layer or a crystallization accelerating layer between said recording layer and said upper inorganic layer.

10. The optical recording medium according to claim 2, wherein said recording layer is a phase change-type recording layer.

11. The optical recording medium according to claim 2, wherein a distance between said optical head to be used in combination with said recording medium and said recording medium is not more than 1 μm.

12. The optical recording medium according to claim 2, wherein said optical head to be used in combination with said recording medium is a flying optical head.

13. The optical recording medium according to claim 2, wherein said upper inorganic layer satisfies said feature A).

14. The optical recording medium according to claim 13, wherein said first dielectric layer has a thickness greater than a thickness at which the minimum

thickness of the second peak region of the reflectivity of said optical recording medium in relation to increase in the thickness of said first dielectric layer is generated by the optical interference.

15. The optical recording medium according to claim 13, wherein said first dielectric layer has a thickness less than 1 μm.

16. The optical recording medium according to claim 13, wherein said first dielectric layer is an inorganic material layer having a refractive index of not less than 1.70 at a wavelength of said optical beam for recording or reproducing.

17. The optical recording medium according to claim 13, wherein said first dielectric layer comprises fifth and sixth dielectric layers in this order on said recording layer, said sixth layer having a higher hardness than that of said fifth dielectric layer.

18. The optical recording medium according to claim 2, wherein said upper inorganic layer satisfies said feature B).

19. The optical recording medium according to claim 18, wherein said metal layer is made of a material comprising at least one of Au, Ag, Cu and Al as a main component and has a thickness of 5 to 50 nm.

20. The optical recording medium according to claim 18, wherein said second and third dielectric layers are an inorganic material layer having a refractive index of not less than 1.70 at a wavelength of said optical beam for recording or reproducing.

21. The optical recording medium according to claim 18, wherein said third dielectric layer has a higher hardness than that of said second dielectric layer.

22. The optical recording medium according to claim 2, wherein said recording medium has a reflectivity which is required by a standard for said recording medium.

23. The optical recording medium according to claim 22, wherein said standard is the ISO standard.

24. The optical recording medium according to claim 22, wherein said recording medium has a reflectivity in a range of 20 to 50% as the higher reflectivity between the recorded and erased sates of information.

25. A method for recording and reproducing an optical recording medium,

providing an optical recording medium comprising a substrate, and at least a recording layer and an upper inorganic layer formed in this order on said substrate, and

recording and reproducing by applying an optical beam to said recording medium from an optical head located on the side of said upper inorganic layer,

wherein said upper inorganic layer is so constructed that a foreign material present on the top surface of said optical recording medium does not evaporate when said optical beam for recording is applied to said recording medium.

26. The method according to claim 25, wherein said upper inorganic layer has one of the following two features:

A) said upper inorganic layer comprises a first dielectric layer having such a thickness that, when said optical beam for recording is applied to said recording medium, the temperature of the top surface of said recording medium does not increase to a level at which a foreign material present on the top surface of said optical recording medium evaporates; and

B) said upper inorganic layer comprises such a laminate of a second dielectric layer, a metal layer and a third dielectric layer in this order on said recording layer, whereby when said optical beam for recording is applied to said recording medium, the temperature of the top surface of said recording medium

does not increase to a level at which a foreign material present on the top surface of said optical recording medium evaporates.

27. The method according to claim 26, wherein said foreign material is mainly water.

28. The method according to claim 26, wherein said top surface of said recording medium does not increase to more than 150°C when said optical beam for recording is applied to said recording medium.

Fig.1

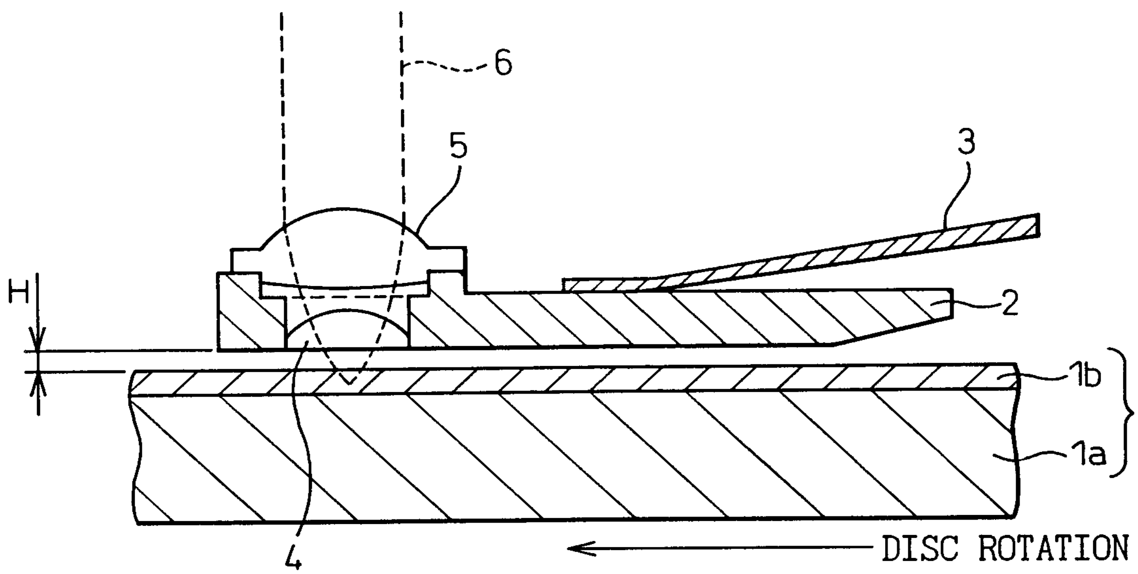

6
5
3
H
2
1b
1
1a
4
DISC ROTATION

Fig.2

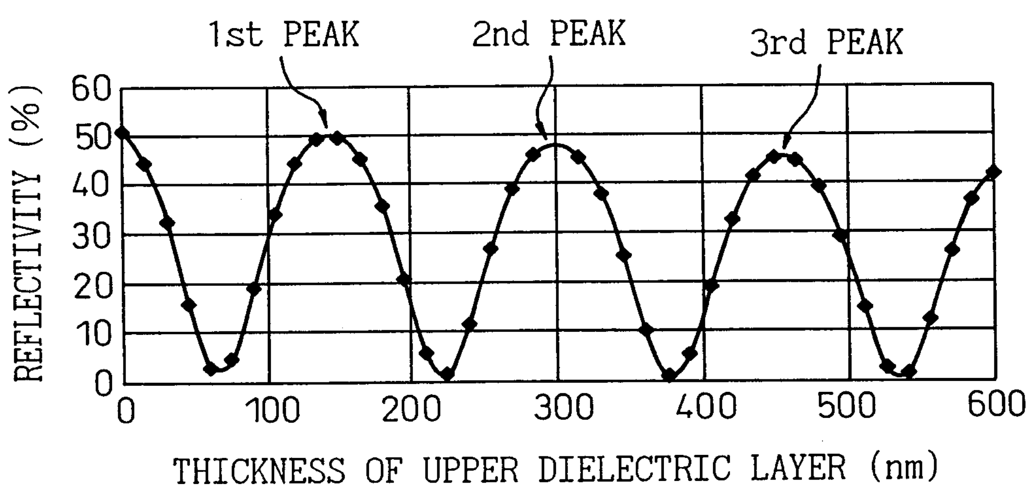

1st PEAK
2nd PEAK
3rd PEAK
REFLECTIVITY (%)
60
50
40
30
20
10
0
0
100
200
300
400
500
600
THICKNESS OF UPPER DIELECTRIC LAYER (nm)

Fig.3

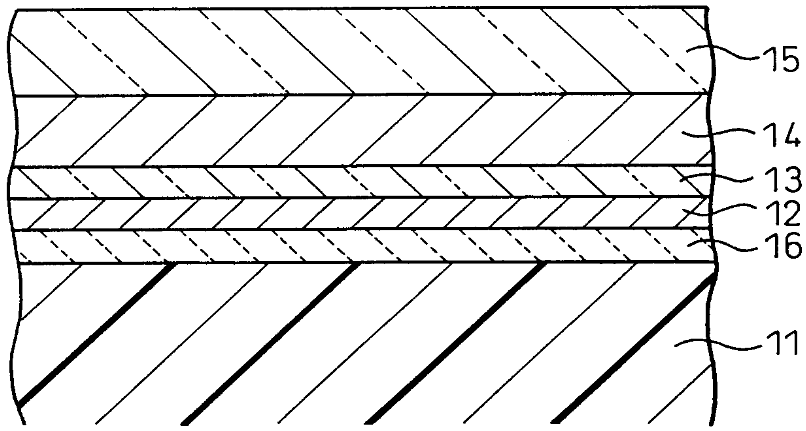


Fig.4

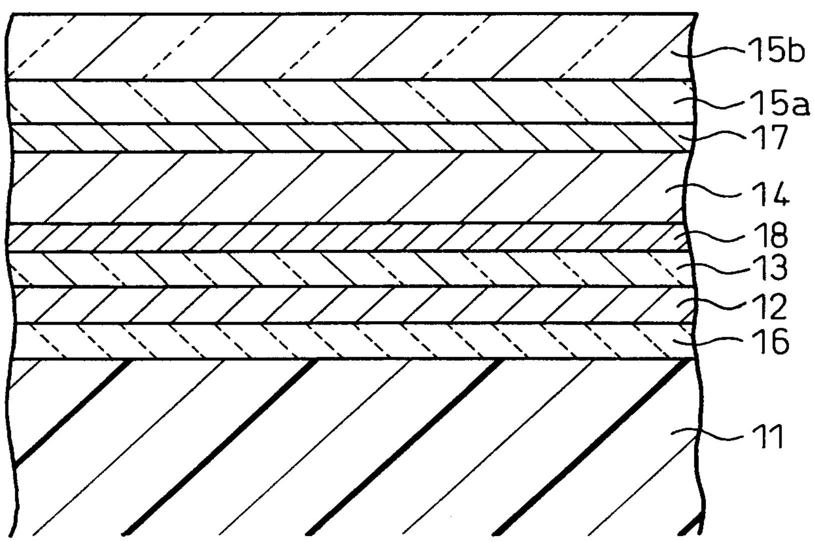
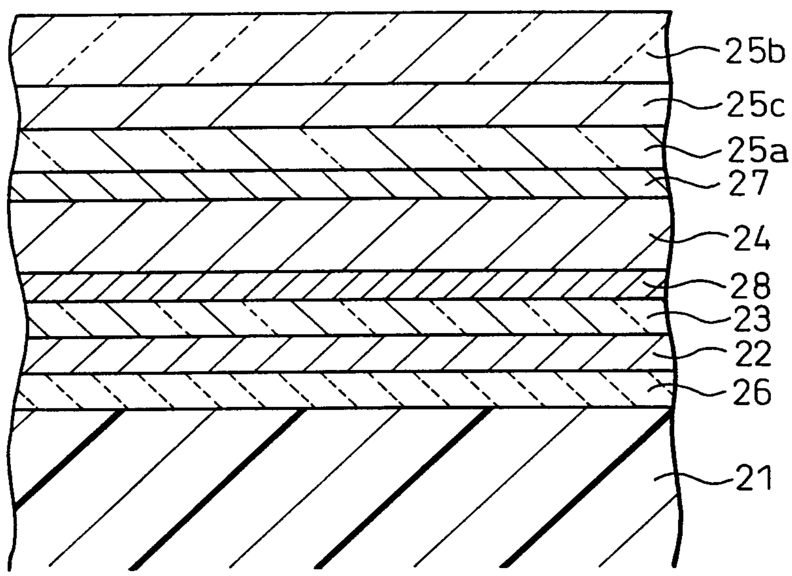


Fig.5



INTERNATIONAL SEARCH REPORT

Int· ·ional Application No
PCT/JP 00/02551

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G11B7/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G11B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 516 178 A (NEC) 2 December 1992 (1992-12-02) column 1, line 27 - line 34; claims 1,2,4,5 column 4, line 10 -column 5, line 30; figures 3-6	1,2
X	EP 0 871 164 A (TDK) 14 October 1998 (1998-10-14) page 7, line 41 -page 9, line 21; claim 1	1,2
X	US 5 656 370 A (M.MURAKAMI) 12 August 1997 (1997-08-12) column 4, line 45 -column 5, line 15 column 6, line 42 -column 7, line 10 column 8, line 33 - line 65; figures 1-3	1,2

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search	Date of mailing of the international search report
27 June 2000	04/07/2000

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Inte   ional Application No
PCT/JP 00/02551

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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